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Research paper

Development of new polymer composite materials for the flooring of rail carriage

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Abstract

The subject of improving the competitiveness and efficiency of railway rolling stock is highly demanded as the railway transport consider the nerve of the goods transport in the hole word. One of the requirements to develop the railway transport related to the continuous improvement of existing materials and find a new material which would satisfy such conflicting requirements as relia-bility, sustainability, producibility and the manufacturing process automation possibility. The researches show that use of polymer composite materials (PCM) in the production of both passenger and freight railway rolling stock, provides lightweight, improves its performance, increases durability and reduces operating costs.

Keywords: *Polymer Composite Material; Cold Pressing; Calico; Fiberglass; Mechanical Properties.*

1. Introduction

Composites materials can be defined as materials consisting of two or more components (reinforcing elements and a matrix holding them together) and having properties different from the original properties of the components [1,2] (Fig. 1).

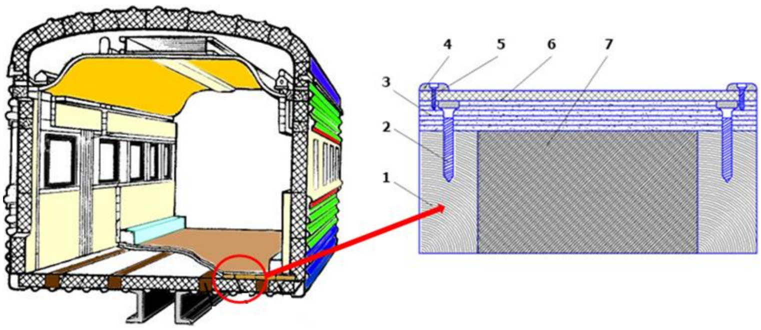

Fig. 1: Polymer Composite Material as A Floor of A Passenger Carriage: 1 – Carriage Body Structure (Jumper); 2-5 - Self-Tapping Screws; 3 - Polymer Composite Material; 4 - Baseboard; 6 - Linoleum; 7 - Thermal Insulation Layer.

It is assumed that the components that make up the composite should be well compatible and not dissolve or otherwise absorb each other. Composite material should possess properties that none of the components separately can possess [3-6]. Only under this condition does it make sense to use them in a design. Polymeric materials also belong to composites, since in addition to the main component (polymer), they contain various fillers, dyes, etc. Polymers are substances whose macromolecules consist of numerous elementary units of the same structure.
The mechanical properties of polymeric materials are determined by the level of elastic - strength properties, glass fibres and matrices, their ratio and bond strength at the interface [7]. The chemical composition of the polymer is expressed by this structural unit, and the number of units (n) in the macromolecular chain is called the degree of polymerization.
Composite material (CM) consists of a binder component (matrix) and reinforcing materials. The role of the matrix in the CM consists of shaping and creating a monolithic material. Combining the reinforcing filler in one piece, the matrix is involved in providing the bearing capacity of the composite. Fillers are introduced into polymers to create new polymeric materials to impart strength properties to the material.

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The study aims to manufacture of polymer composite materials for the replacement of wooden plywood boards used for flooring of railway passenger cars.

2. Materials and research method

To experiment, the method of pressing the composite into moulds was used. The non-cured Diane epoxy resin grade ED-20 GOST 10587-84 [8] was used as a binder material for the “matrix”, and polyethene polyamine hardener was used as a hardener. To give colour, an alcohol-based gel paste was used as a dye. The ratio of epoxy resin to hardener has wide limits and depends on its composition and properties. To obtain glue, the epoxy resin was mixed with the hardener at room temperature in a ratio of 1:10. As a reinforcing filler used fibreglass, fibreglass mesh, fibreglass, calico, as well as calico together with fibreglass and calico together with fibreglass.
The mould for pressing the composite has an internal size of 120 × 120 × 15 mm, the mould design is detachable, the sidewalls and the bottom are attached using self-tapping screws. Pressing is a technological process of manufacturing products from polymeric materials, which consists in the plastic deformation of materials under the influence of pressure and subsequent fixation of the shape of the product (Fig. 2).

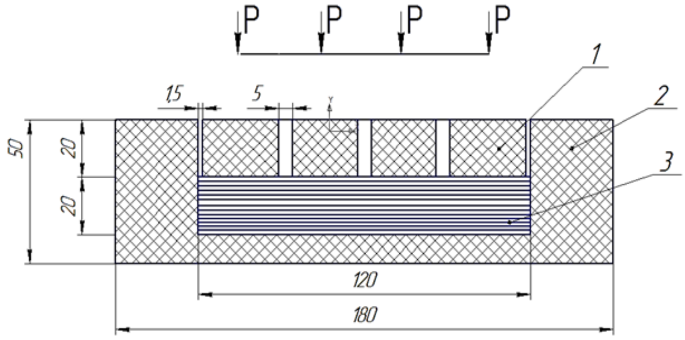


Fig. 2: Scheme of Cold Pressing of Composites: 1 - Cover with A Press; 2 - Form; 3 - Molded Composite.

For pressing the formed samples, a weight of 8 kg was used. The main forming tool is mold. The time for complete polymerization of the composite in the mold under the press was 24 hours.
Preparation of samples for mechanical testing began with cutting the composite with a file into billets with a size of 124 × 34 × 14 mm, followed by grinding to a size of 120 × 30 × 10 mm (Fig. 3). Grinding composites under GOST 26277-84 was used both for roughing and for finishing and finishing processing of samples [9].

Fig. 3: General View of the Samples After Grinding.

Mechanical tensile testing of composite materials with a polymer matrix (composites) was carried out per GOST 25.601-80 (ISO R527), tensile - following GOST 11262-80, bending - under GOST 25.604-82. All types of tests of epoxy composite samples were carried out at room temperature 18-20 ° C on standard equipment [10-12].
Physio - Mechanical properties of the tested samples are presented in table 1-3, and the typical types of destruction of the samples during mechanical testing are shown in table 4.

Table 1: Physio - Mechanical Properties of the Tested Samples

Reinforcing fillers samples	Density, g/cm^3	Tensile strength σ_t, Mpa	Bending strength σ_B, Mpa	Relative extension, %	Brinell hardness, HB	Wear Rresistance, %	Shrinkage when treatment, %	Working temperature, °C
Fiberglass 1 2 3	1,3	69,6 87,0 73,3	349 362 357	4,5	36	13	1,3	–40 +140
Fiberglass mesh 1 2 3	1,2	44,0 44,6 45,0	173 178 170	3,7	35	12	1,5	–40 +120
Glass mat 1 2 3	1,2	9,3 8,6 8,3	125 122 119	1,6	34	10	1,0	–40 +120

Table 2: Comparison of the Physio - Mechanical Properties of the Epoxy Composite Material with Various Materials

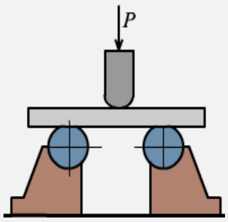
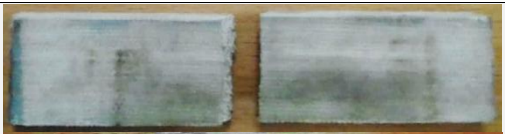
Indicators	Materials						
	St3	Steel grade 45	D16	AMg6	Composite Evolution Motors LLC	Plywood board	Epoxy composite
Density, g/cm^3	7,8	7,8	2,8	2,6	1,6	0,55	1,5
Tensile strength σ_t, Mpa	125	220	270	147	138	85	100
Bending strength σ_B, Mpa	140	275	270	148	102	80	195
Working Temperature, °C	–50 +400	–50 +400	–40 +250	–40 +220	–40 +110	–40 +140	–40 +140
Hardness, HB	200	200	105	65	37	12	36
Elongation, %	5	14	16	19	4,0	5,2	4,5

Table 3: Physio-Mechanical Properties of Samples Based on Cotton Calico

Reinforcing sample fillers	Density, g/cm3	Tensile strength σ_t, Mpa	Bending strength σ_B, Mpa	Relative extension, %	Brinell Hardness, HB	Wear-resistant g/cm^2	Shrinkage when treatment, %	Working Temperature, °C
Calico 1 2 3	1,2	65 66 67	227 229 225	1,8	36	1,3	1,3	–40 +130
Calico and Fiberglass 1 2 3	1,3	118 119 117	397 412 410	2,7	35	1,2	1,5	–40 +140
Calico and fiberglass mesh 1 2 3	1,2	110 100 106	265 287 290	2,2	34	1,0	1,0	–40 +130

Table 4: Typical Types of Destruction of Samples from Composite Materials

№	Type of Loading	Material	Samples after Test	Evaluation
		Fiberglass		+
	Tensile	Fiberglass mesh		+
1		Glass mat		-
		Calico		-
		Fiberglass + calico		+
		Fiberglass		+
2	Bend	Fiberglass mesh		+
		Glass mat		-

	Calico		-
	Fiberglass + calico		+

3. Results analysis

The relationship between the matrix occupancy and the mechanical properties of the composite material correlates well with the types of fracture presented in Table 4. As can be seen, the fracture pattern of composite materials reinforced with fiberglass and fiberglass has the form of viscous fracture. For composite materials reinforced with glass mat and calico, brittle fracture of the material was revealed.
Samples reinforced with coarse calico have an average strength of $\sigma_b = 66$ MPa (Table 3), and brittle fracture of the samples is observed. It should be noted that the use of coarse calico as a filler is quite technologically advanced since there is a good matrix occupancy. However, the fragile nature of the destruction of the material does not allow us to recommend calico as an individual filler for the purposes considered in this work.
It is interesting that the highest complex of mechanical properties, among the studied composite materials, was shown by samples that were reinforced together with coarse calico and fiberglass (table 3). Samples reinforced with coarse calico and fiberglass (the ratio of materials is 50 to 50% showed higher mechanical properties than samples reinforced with coarse calico and fiberglass. The strength of samples based on coarse calico with the addition of fiberglass is on average $\sigma = 100$ MPa (Table 3), also, the type of destruction of the samples has a more viscous character (table 4), which is preferable for the manufacture of the investigated flooring.
Thus, the results of the study of the macrostructure of polymer samples showed that reinforced polymer matrices under mechanical loading are capable of plastic deformation up to destruction. The samples reinforced with glass material, due to the reinforcing filler, have higher ductility and strength.

4. Conclusion

The work carried out comprehensive mechanical tests of a composite material based on an epoxy matrix with various fillers. It was established that the samples of polymer composite material reinforced together with coarse calico and fibreglass possess the highest complex of mechanical and technological properties.
Based on the analysis of mechanical and technological properties, it is recommended that the flooring of passenger cars was made from a polymer composite material based on an epoxy matrix reinforced together with calico and fibreglass.

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